MODELLING BOSE-EINSTEIN EFFECT FROM ASYMMETRIC SOURCES IN MONTE CARLO GENERATORS[a]

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We present some results concerning the Bose-Einstein effect in asymmetric sources in Monte Carlo generators. A comparison of LEP data, standard JETSET predictions and results from the weight method is given. Possible generalization of the weight factors to an asymmetric form is considered.

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1 Introductory remarks and data

Recently we observe a renewal of interest in analysing the space-time structure of sources in multiparticle production by means of Bose-Einstein (BE) interference. Such analysis followed the example of astrophysical investigations of Hanbury-Brown and Twiss [1]. By improving the standard approach [2] it became possible to model this effect in Monte Carlo generators: as the "afterburner" for which the original MC provides a source [3,4], by shifting the momenta [5] or by adding weights to generated events [6,7].

The analysis of BE effect in 3 dimensions is supposed to reflect the spatial source asymmetry. Such analysis was done for the LEP data at the Z^0 peak [8] which have very high statistics and good accuracy. In the following we concentrate our attention on the L3 data [9], as the DELPHI data [10] are parametrized with only two radii, and the OPAL data [11] use the like/unlike ratio which requires a cut off of the resonance affected regions even in double ratios.

As in the L3 paper [9] we use for each pair of identical pions three components of the invariant $Q^2 = -(p_1 - p_2)^2$: $Q_L^2, Q_{out}^2, Q_{side}^2$ defined in the LCMS, where the sum of three - vector momenta is perpendicular to the thrust axis. Similarly we define a "double ratio" using a reference sample from mixed events:

$$R_2(p_1, p_2) = \frac{\rho_2}{\rho_2^{mix}} / \frac{\rho_2^{MC}}{\rho_2^{mix,MC}}.$$

This "double ratio" is parametrized by

$$R_2(Q_L, Q_{out}, Q_{side}) = \gamma[1 + \delta Q_L + \epsilon Q_{out} + \zeta Q_{side}] \cdot$$
$$\cdot \; [1 + \lambda exp(-R_L^2 Q_L^2 - R_{out}^2 Q_{out}^2 - R_{side}^2 Q_{side}^2 - 2\rho_{L,out} R_L R_{out} Q_L Q_{out})]$$

The first bracket reflects possible traces of long-distance correlations; the last term in the second bracket seems to be negligible when fitting data and will be omitted in the following.

By fitting the parameters R_L and R_{side} we get some information on the geometric radii in the longitudinal and transverse directions (respective to the thrust axis). R_{out} reflects both the spatial extension and time duration of the emission process.

In the L3 data the fit region in all three variables extends to 1.04 GeV and is divided into 13 bins, which gives 2197 points fitted with 8 parameters. The fit parameters δ, ϵ and ζ are rather small; this means the observed BE enhancement is rather well approximated with a Gaussian.

The fitted values of radii (in **fm**) are as follows:

$$R_L = 0.74 \pm 0.02^{+0.04}_{-0.03}, \;\; R_{out} = 0.53 \pm 0.02^{+0.05}_{-0.06}, \;\; R_{side} = 0.59 \pm 0.01^{+0.03}_{-0.13}$$

We see clear evidence for source elongation: R_{side}/R_L is smaller than one by more than four standard deviations.

2 Asymmetric effects from symmetric models

The geometric interpretation of data requires a comparison with the results from the standard MC procedures modelling the BE effect. In the L3 paper such an analysis is given for the standard LUBOEI procedure built into the JETSET Monte Carlo generator.This procedure modifies the final state by a shift of momenta for each pair of identical pions. The shift is calculated to enhance low values of Q^2 and to reproduce the experimental ratio in this variable. The superposition of the procedure for all the pairs and subsequent rescaling (restoring the energy conservation) makes the connection between the parameters of the shift and the resulting ratio rather indirect.

Using the JETSET parameters adjusted to all the L3 data and the LUBOEI parameters fitted to describe the BE ratio in Q^2 the authors of the L3 paper calculated the same quantities

as measured in the experiment. The projections of R_2 look qualitatively very similar to the experimental ones. However, the fit to the 3-dimensional distribution gives results different from data. The ratio R_{side}/R_L is not smaller but greater than one; the fitted values (in **fm**) are:

$$R_L = 0.71 \pm 0.01, R_{out} = 0.58 \pm 0.01, R_{side} = 0.75 \pm 0.01.$$

We confirmed these numbers in our calculations. We found also that the results are sensitive to the JETSET parameters. Using the default values instead of the L3 values we obtained a significantly smaller value of R_{out} (below 0.5) and significantly smaller λ. Other values are less affected and R_{side}/R_l still bigger than 1.

We have checked also how the results depend on the source radius R and incoherence parameter λ_{in} assumed in the LUBOEI input function $R_{BE}(Q) = 1 + \lambda_{in} exp(-R^2Q^2)$. In all cases we get $R_{side} > R_L > Rout$, although the input function was obviously symmetric. The values of R_{side} and R_L are proportional to R, whereas R_{out} changes much less; the dependence on λ_{in} is very weak. The output value of λ decreases quite strongly with increasing R and increases with λ_{in}. No choice of input parameters gives the values of R_i compatible with data. This is shown in Fig. 1.

Another interesting observation is that to fit the L3 data one needs $\lambda = 1.5$, which is beyond the physically acceptable value of 1. This supports our doubts about the usefulness of the LUBOEI procedure in understanding the experimental results (although certainly it is the most practical description of data).

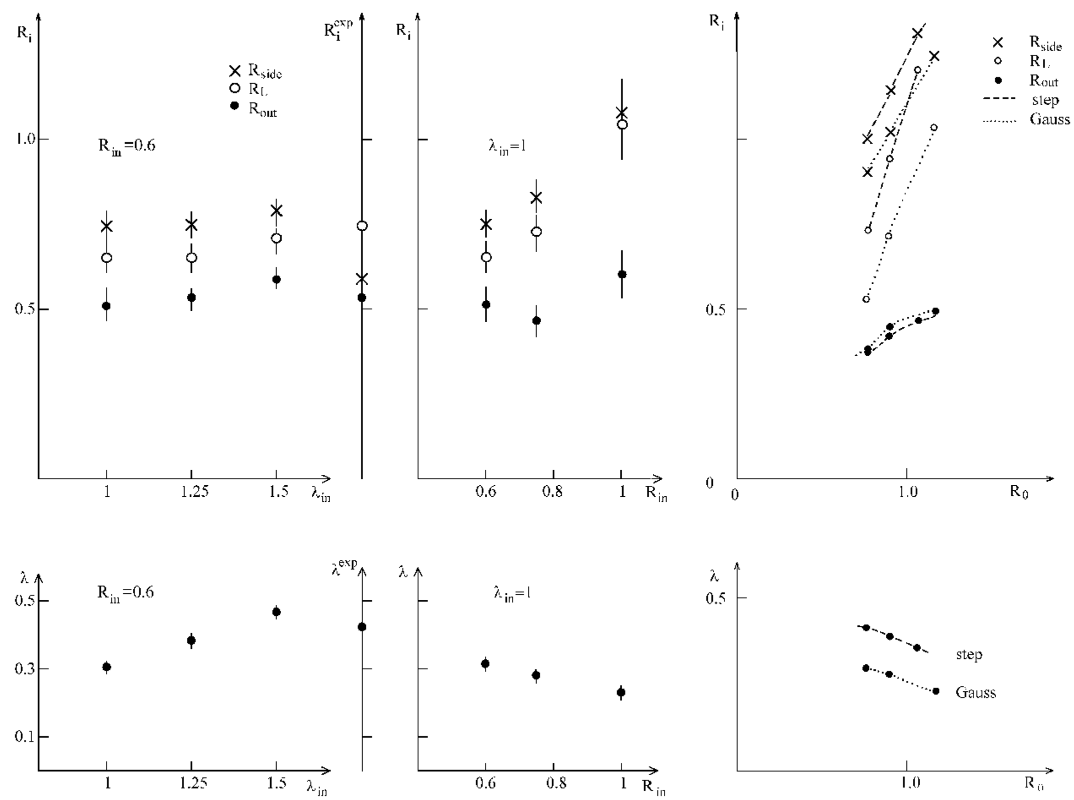

Figure 1: Fit parameters λ and R_i as functions of the input parameters a) for the LUBOEI procedure, b) for the weight method. Experimental values are shown on a separate vertical axis.

Therefore we have also compared the data with the results from another procedure modelling the BE effect - the weight method [7]. In this method each event gets a weight calculated by summing the products of two particle weight factors, which are just 1 for equal momenta and

vanish for large separation in momentum space. A reasonable description of the effect in Q^2 is obtained with a simple gaussian form of the weight factor

$$w_2(p,q) = exp[-(p-q)^2 R_0^2/2], \tag{1}$$

or, even simpler, θ - function form with $w_2 = 1$ for some range of $-(p-q)^2 < 1/R_0^2$ and $w_2 = 0$ outside.

In this method we may repeat the same calculation as done for the LUBOEI procedure. The resulting double ratios are not that smooth and monotically decreasing as in the data or from the LUBOEI procedure (which is the usual drawback of the weight methods). However, the major features are surprisingly similar: with weight factors depending only on Q^2 we get different values of fitted R_i parameters. Moreover, the hierarchy of parameters is the same: $R_{side} > R_L$. This suggests that the assymetry is generated by the jet-like structure of final states and not by any specific features of the procedure modelling the BE effect. In Fig. 1b we show the values of the fit parameters as functions of R_0 for a Gaussian as well as the θ-like weight factors. Again, no choice of input parameters allows to describe the data.

These results suggest also that one should be careful with the geometric interpretation of the data. If one gets asymmetric distributions from the generator without assuming explicitly space asymmetry of the source, it is not clear how the assumed asymmetry will be reflected in the results.

We tried to get some information on this problem within the asymmetric weight method, i.e. introducing weight factors which depend in a different way on Q_L, Q_{side} and Q_{out}. This work is progress. However, it seems rather difficult to reproduce the data even with two more parameters.

3 Conclusions and outlook

In this note we investigated the asymmetry of the BE effect in two procedures imitating this effect in the Monte Carlo generators and compared them to the data at Z^0 peak. Both procedures give surprisingly similar results and disagree with data. The work on the possible introduction of asymmetry in the weight method is in progress.

Acknowledgments

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